Multiple-factor adoption of GM Cotton in China: Influence of conventional technology development and rural change in Jiangsu Province

Naiyin Xu, Michel Fok

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Naiyin XU[1] and Michel FOK[2]

[1] Jiangsu Academy of Agricultural Sciences, Institute of Industrial Crops, Nanjing (China)
[2] CIRAD, Montpellier (France)

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Abstract

The large diffusion of Genetically Modified Cotton (GMC) in China, namely Bt-Cotton, has been well evidenced but recent report on its reduced profitability raises the issue of long term adoption. This paper targets to point out that the adoption of Bt-Cotton in China has not depended only on its specific advantages in controlling pests. It focuses on the specific case of Jiangsu Province, along the Yangtze River Valley, for which the use of GMC is little reported in publications accessible to most scientists of the international community. The paper synthesizes the recent analyses published in Chinese from people involved either in research or in extension activities and it exploits the results of a survey implemented in 2005 as well as the data of the network of multi-location experiments of cotton varieties in the Yangtze River Valley. It comes out that in Jiangsu Province, the diffusion of GMC has benefited a lot from the modernization of the seed sector which has integrated Bt trait into hybrid cultivars which are perfectly adapted and profitable to the transplanting technique. In spite of a rather limited reduction in the cost of pest control, farmers should not abandon using Bt-Cotton, because the evolution of Chinese farming does not push cotton growers to be so much vigilant in optimizing their production costs, unless seed prices keeps on tremendously increasing. The continuation of a profitable use of GMC should require some move to better regulate the seed sector.

Keywords:

Bt-Cotton, China, farming, hybrid, seed market, transplanting

1. Introduction

In China, the commercialization of Genetically Modified Cotton (GMC) started in 1997, with varieties integrating a Bt gene to control the attack from some cotton pests (Bt-cotton). Many research papers, nevertheless based on the results of the same team, contributed to popularize the idea of successful adoption of Bt-cotton in China. These papers targeted at demonstrating the profitability gain and the reduction in pesticide use associated to Bt-cotton varieties (Huang, Hu, et al., 2004; Huang, Hu, et al., 2002a; Huang, Hu, et al., 2002b; 2003; Huang, Pray, et al., 2003; Pray, Huang, et al., 2002). With reference to the large extent of GMC coverage, estimated at about 60% of the total cotton area in China, the success of the GMC diffusion must indeed be acknowledged.

The picture of this adoption is nevertheless more complex as cotton growing conditions are very diverse in China. While the results published in foreign language pertained mainly to the Yellow River Valley where the insecticide resistance of the cotton bollworm (Helicaverpa armigera) was the most severe before the GMC introduction, results in two other major cotton producing regions are little reported. The Xinjiang Province is the major cotton producing region in China, contributing for about one third of the Chinese cotton production. In this semi-arid continental region, the pressure of H. armigera is still very low: there is no use of Bt-cotton and little rationale for this use. The Yangse River valley is the third cotton region which encompasses eight cotton producing provinces where the pressure of H. armigera has always been lower than in the Yellow River Valley. A few articles, published in Chinese, yet underlined a far smaller effect of Bt-cotton in the reduction of the number of chemical sprays against H. armigera , leading to a less profitability, if any, of GMC use (Xu, You, et al., 2004; Xu and Ji, 2005; Zhang and Zhou, 2003).

Even in the Yellow River Valley, a recent communication clearly questioned the continuation of the profitability of the Bt-cotton use because of the need to control more against formerly secondary pests and of the increasing cost of planting seeds (Lang, 2006). The threat of mirids against the sustainability of Bt-cotton success in China is now acknowledged (Anonymous, 2006), the threat against the long term effectiveness is now taken into consideration in China (cricaas, 2006) while the signs of a more global change in the cotton pest complex, consecutive to the use of Bt-cotton, is not yet sufficiently publicized. Several Chinese papers have yet emphasized the increasing damage of another Lepidoptera (Spodoptera litura or Prodenia litura) whose caterpillar, so far leaf eating, is attacking all fruit organs (Guo, Dong, et al., 2003; Li, 2004; Li, Wang, et al., 2004; Qin, Ye, et al., 2000). Hence, could the reduction of the Bt-cotton effectiveness lead farmers to move back from using it?

The objective of this paper is to provide some comprehensive vision about the features of the diffusion of Bt-cotton in China. We contend that some reduction in the effectiveness of Bt-cotton in China will not necessarily be the main reason that might lead farmers to move back to conventional cotton varieties because the diffusion of Bt-cotton was not only based upon the advantage of pest resistance, at least in some provinces. In China, there was a continuous chain of remarkable technology development prior to the GMC introduction. The diffusion of GMC benefited from the existing technologies and reversely, within a dramatic modernisation of the seed marketing. There was hence a phenomenon of technology integration which favours the use of Bt-cotton. Besides, this integration was also implemented within a dramatic change in the commitment in farming activities. Agriculture appears to be kind of secondary activity (Fok, Liang, et al., 2005) for which less attention might be given to its optimisation. Consequently, farmers could keep on using Bt-cotton more than justified because they do not try so much to get seeds of non-Bt-cotton which meanwhile also have become harder to find.

This paper is devoted to emphasize the roles of the two phenomena above mentioned, so far little taken into account by most of the research works dealing with the Bt-cotton adoption in China. It exploits the recent analyses published in Chinese from people involved either in research or in extension activities. Specific attention is paid to the case of the Yangtze River Valley, by making use of a survey implemented in various districts of Jiangsu Province in

2005 and of the results of the network of multi-location experiments of cotton varieties in the Yangtze River Valley. The survey was conducted in 176 farms scattered in four districts (LianYunGang, NanTong, YanCheng, TaiZhou). The conduct of the survey was nevertheless not optimal. We did not succeed to have all farmers responding to the questions to capture production costs and those who responded did not answer to all questions. Consequently, statistic analysis is limited and the information related to production costs must be considered only for indicative value before confirmation by additional research works.

This paper is organized as follows. In section 2, the relative place of cotton production in Jiangsu Province is reminded and it will be elaborated the development of the major technologies which favoured the use of Bt-Cotton. In section 3, the main features of the cotton growing practices in Jiangsu Province will be pointed out and the impact of the GMC trait on productivity and profitability will be appraised. In Section 4, the influences of various factors sustaining the use of Bt cotton will be presented and discussed.

2. Cotton Production and adoption of new technologies in Jiangsu Province

2.1. Cotton production and processing in Jiangsu Province

Cotton production has a long history in Jiangsu Province of about 700 years but upland cotton was introduced only in 1904 after the development of textile industry in the area by the end of the 19th century (Agricultural Science Association of Jiangsu Province, 1991). Production statistics are kept since 1919. During the 1919-48 period, a very disturbed one in the Chinese history, the average of cotton area was 550,000 ha with a lint yield of 186 kg/ha.

Since then, Jiangsu Province has become an important place both for cotton production and processing. In the 1981-2002 period, this province accounted for 35% of the cotton area along the Yangtze River Valley. At the national level, this province ranks fifth with 10% of the total cotton area. The average lint yield was 868 kg/ha, above the national mean. With regard to cotton processing in textile industry, Jiangsu Province has increased substantially its mill use of 800,000 metric tons by the end of the 1980s to 1,300,000 metric tons in 2004. This figure is about three times of the local production and it is representing about 1/5 of the total mill use in

China.

The farmers' commitment in cotton production nevertheless is declining, since 1995, after a drastic change in the support policy to cotton before China entered WTO. The cotton area has decreased by about 50% as compared to the first half of the 1980s (Table 1). The in-depth analysis of this decline goes beyond the scope of this paper, it suffices here to underline that the great fluctuations of the purchase price of seedcotton[1] discouraged farmers who can shift to more profitable alternative crops (Yu, Zhu, et al., 2004), in particular to cereals after the Chinese government applied area-based direct-payment to promote cereal production in 2004.

Consequently, productions decreased but not at the same extent than area reduction because of a remarkable yield gain (Xu and Ji, 2005). This yield gain took place prior to the Bt-cotton introduction, thanks to various technology breakthroughs which are little known out of China, and which were fortunately combined with Bt-cotton to sustain the yield gain process. Indeed, nowadays, cotton growing clearly is intensive with farmers showing good technical command. Cotton producers make use of various chemical inputs. In addition to high level of fertilizing based upon mineral fertilizers and of chemical control of cotton pest, farmers systematically apply growth regulators and frequently install cotton plants on plastic mulch. Farmers do not hesitate in labour investment in their yield maximisation approach. They often eliminate vegetative branches during the fruiting stage and top cotton plants to enhance boll growth. This brief description indicates the amount of technologies and knowledge passed to farmers. Hereafter, we only insist on the two major technologies which favour the diffusion of GMC, namely cotton transplanting and cotton hybrids.

2.2. Genesis, development and adoption of the transplanting technique

In China, the research on cotton transplanting originated in Jiangsu Province. The Chinese

[1] Per 50 kg of cotton lint, the purchase prices were 617, 390, 540, 340, 480 and 820 Yuan respectively for the years 1998, 1999, 2000, 2001, 2002 and 2003.

government was concerned by meeting the needs in cereal and cotton lint of an increasing population while China represents only 7% of the world arable land. Double-cropping was the keyword, but the constraint was the possible occurrence of early frost. The technical challenge was to install cotton crop right after the harvest of wheat or barley and to ensure that cotton bolls would open before frost. The contemplated solution was to implement production of cotton seedlings in nurseries and to transplant immediately after the harvest of cereal. The research works started in 1954 and first demonstration at farmers' level was conducted by 1955. The collectivist system could be part of the reasons why no real adoption followed: the labour intensity was not compatible with a system not showing incentives to individuals. The technique itself was not perfectly mastered, notably at the nursery stage. The low temperature when cotton sowing was implemented led to insufficient germination rate and reduced seedling growth. The transplantation hence was implemented with seedlings which were not strong enough to recover. This issue could be potentially solved with the development of the plastic film industry in the early 1960s. In reality, the research works were resumed substantially in the late 1970s, after the liberalization of the agricultural economy.

The adoption of cotton transplanting really occurred during the 1980s in Jiangsu Province (Table 2). It was noted that more than 90% of cotton producers implemented cotton transplanting in 2000 (Li, Ji, et al., 2000) and now one can hardly find a single cotton producer not implementing this technique in this Province. This technique is also extensively adopted in other provinces along the Yangtze River valley as well as in some northern provinces along the Yellow River valley, Jiangsu Province only accounted for 35% of the total cotton transplanted area in 1990 (Zhu, Ni, et al., 1991).

The transplanting technique now is perfectly commanded and its diffusion is due to its effectiveness and to various advantages it brought. In practice, the implementation of the transplanting technique encompasses five stages: soil preparation, making of nutritious blocks, sowing in nursery, transplanting and appropriate water management and fertilizing afterwards.

The preparation of the soil to be used in nursery is particular. It is recommended to reach organic matter content over 2%. Minimum contents of available nitrogen, phosphorous and potassium also are determined. Sowing in nursery is operated on blocks of soil which are called "nutritious blocks" made from the soil previously prepared. Machines have been carried out to manufacture the "nutritious blocks". A "pedal block press" can help to produce 5,000-6,000 blocks par day by a skilled worker. Blocks are cylinders of 6-7 cm in diameter and 7 cm high. A small dip of 1.5 cm deep is formed at the upper surface of each block where seed is sown. Sowing in nursery can be implemented through two possible ways. One is to install the sown blocks into a plastic-covered frame. Another way is to plastic-mulch the sown blocks directly. The transplanting is implemented according to well-determined conditions. It is recommended to transplant after the soil temperature is above 19° C. Cotton seedlings of 3-4 leaves stage are optimal. Seedlings are moved into pits previously dug and fertilized. Densities vary according to locations but are anyway lower than in direct sowing because of the plant stronger vigour. Water management, and furthermore fertilizing of the cotton plots, must be adjusted to the higher yield resulting from greater growth and development observed with transplanted cotton plants.

Briefly speaking, the main root is shortened during the transplanting process and this is favourable to the development of primary branch roots and their assimilation capacity. As compared to direct sowing, transplanted cotton plants also show larger leaf area, earlier development, earlier boll forming, and greater number of early and middle bolls. More bolls which weighed more (Table 3) lead to a yield increase of about 35% (in experiments of 1980-81).

The technique nevertheless is very labour demanding. The soil preparation and the making of nutritious blocks also require arduous work, even for men. The labour investment is proportional to the plant density. The conception of machineries to alleviate this work constraint has just started (Li, Lu, et al., 2006). As far as no mechanized solution is available, lower the density can be, lower is the labour requirement and better appreciated the technique will be. The supply of hybrid varieties, with more vigorous plants, eventually has helped meet this implicit demand.

2.3. Genesis, development and adoption of cotton hybrids

China very early had paid attention to the creation of cotton hybrids, firstly through inter-specific crossings. The first hybridization was implemented in the 1940s between tetraploids of Gossypium hirsutm from the USA and tetraploids of barbadense obtained from former USSR (Xing, 2004). The first national conference for the creation of cotton hybrids was organized in 1956, the second one did not happen before 1985 (Liu, 1995). The first generation of cotton hybrid plants being obtained were strong and vigorous, showing important growth, great fructification, but their late fruiting after occurrence of frost led to low yields. These hybrids were little exploited.

Attention shifted later to the creation of intra-specific hybrids. A research group dedicated to this topic was formed in the late 1970s. The first hybrids of this generation of intra-specific hybrids were released in the early 1990; the most representative varieties were ZhongMianSuo 28, ShangZaMian 2, YuanZa 40. These cotton hybrids were developed according to the criteria of productivity, fibre quality and resistance to diseases. They did not diffuse so much because the prevailing cultivation technique did not enable them to express their superiority. The farmers' practices in term of planting densities, of late sowing (notably delayed by the harvest of wheat or barley) appeared not to be compatible with the hybrid growth and development features (Liu, Han, et al., 2005). It was the adoption of transplanting which made hybrids more attractive.

When pest resistance to insecticides out broke, firstly in 1992-93 in the northern cotton zone, then in 1998 in the southern part, the genetic resistance to pest became the additional criterion to integrate. It was the second generation of intra-specific hybrids integrating pest resistance, through the introgression of Bt gene, which eventually led to the real development of hybrid use by farmers. At national level, the cotton area under hybrid varieties increased from 130,000 ha in 1998 to 530,000 ha in 2004 (Li and Liu, 2005), which represented about 10% of the total area. In some locations in Henan Province (Yellow River Valley), hybrids are representing 65% of the total cotton area (Ma and Zhang, 2005; Zhang, Wang, et al., 2005). Globally speaking, it is estimated that Bt-cotton hybrids correspond to about 80% of all hybrid cotton area (Xing, 2004). The use of Bt-cotton hybrids firstly started in the YanCheng District of Jiangsu Province, before spreading to Hubei, Hunan, Jiangxi and Anhui Provinces along the Yangtze River Valley and before shifting northward to some provinces, like in Henan and Shandong Provinces (Li and Liu, 2005) with still uncertain success: in Shandong, cotton hybrid still account for less than 15% of the seed market (Li, Zhao, et al., 2005).

The real diffusion of hybrids did not derive only from the yield gain they brought, estimated at 15-25% on average (Xing, 2004). It also has benefited from the additional trait of pest-resistance when most if not all hybrid cultivars have been made incorporating Bt-gene. Overall, the diffusion of hybrid cultivars has resulted from the modernization and development of the cotton seed industry after the introduction of GMC in China.

The large scale of commercialisation of Bt-cotton, firstly through American origin varieties, involved the well acknowledge seed company, Delta & Pineland Company, and it corresponded to a real modernization of the seed market. The supply of cotton planting seeds was somehow revolutionized through the distribution of delinted seeds in attractive packaging, adjusted to the tiny size of the farmers' cotton plots, and through the guaranty on seed germination rate. The combination of the hybrid and GMC traits shortly became the general marketing strategy of seed distributors, in Jiangsu Province and other provinces. This is an approach which protects them against the farmers' temptation to hold back seeds from one season to another and hence to safeguard the seed market size. At national level, the share of the seeds farmers hold back from one season to another was reduced from 30.4% to 16.1% in the 2001-4 period (Lu, Tian, et al., 2006).

This strategy seems to be far more profitable to seed distributors in China. From 1995 to 2005, the labour cost for hybridization has increased from US$1.20 to about 2.22/day (or Yuan 10/day to about 18/day). Consequently, the production cost of hybrid seeds had increased from US$2.90 to 3.95 (or Yuan 24/kilo to Yuan 32/kilo) (Xu, Qian, et al., 1999; Yan, Wang, et al., 2006). In the same time the market price of hybrid seeds has increased from US$12.08 to 31.00/kg (or Yuan 100/kilo to Yuan 251.4/kilo)(Anon., 2004).

The large extent of GMC use in provinces like Jiangsu does not depend only on its sole advantage of pest resistance. Other factors have contributed. In short, along the Yangtze River valley, the command of the transplanting technique ensured the success of doubling-cropping but this technique is labour-intensive and proportionally to the plant density. The use of vigorous hybrid plants enabled to decrease density and consequently reduced labour requirement. The integration of Bt-gene further enhances the advantages of using hybrids. The prospects of a promising seed market push breeders to implement this integration. The analysis of how farmers are growing cotton provides more evidence about this phenomenon.

3. Features of GM Cotton use in Jiangsu Province

3.1. Diversity and changing picture of the cotton varieties used

Farmers are using a large range of cotton varieties. During the 2004 and 2005 campaigns covered by our survey, 33 distinct varieties were encountered. Farmers are showing a great versatility in the varieties they use: while 14 were maintained from 2004 to 2005, 7 were abandoned after 2004 and 12 were newly used in 2005. This result reflects the real situation of excessive varietal choices in China. In 2001, there were 120 varieties officially registered for commercial release. This figure was increased to 266 and 300 respectively in 2004 and 2005 (Lu, Tian, et al., 2006). This is an indication of how harsh the competition between cotton varieties now is.

The large range of varieties being used nevertheless is somehow misguiding since the farmers' preferences are concentrated on a limited number of varieties (Table 4). The most preferred variety could be adopted by 25-37% of all farmers. This was the case for LuMian 15 in 2004, which was retrograded to the third position in 2005 in favour of NanKan 3. About 75% of the farmers are using a sub-group of five varieties. This phenomenon of concentration is confirmed by the interviews with some seed distributors and it is actually prevailing in all cotton provinces. The implication is the reduction of the lifespan of the proposed varieties. This lifespan was 10-15 years during the 1980-85 period, 5-6 years in the 1995-2000 period and no more than 3-4 years in the 2001-2005 period (Lu, Tian, et al., 2006). This is another indication of the harsh competition in the supply of planting seeds as well as of the constraint of some high seed pricing to expect reaching reasonable profitability.

In the surveyed area, hybrid cultivars prevailed among the varieties farmers used. Only 4 non-hybrid cultivars were encountered for the two campaigns. The same apply to the GMC cultivars (Table 5). Farmers are mainly adopting hybrid and GM cultivars: 79% are using hybrid cultivars either GMC or not, while more than 90% are using GMC cultivars, either hybrid or not. Actually, there are only 5.9% using cultivars which are neither hybrid nor GMC.

There are great price differentials among seeds of various types of cultivars. There is a gap of about US$ 80/ha between hybrid and non-hybrid cultivars (Table 5). According to Table 5, the gap between GMC and non-GMC cultivars is close to US$ 50/ha, this figure is in fact misleading in assessing the real price differential derived from the GMC feature because it is biased by the large share of hybrid and GMC cultivars among the varieties used by farmers. In our sample, under the reservation of the small number of farmers not using hybrid or GMC varieties, the GMC feature specifically induced a price differential of US$ 5/ha and 7/ha respectively for hybrid and non-hybrid cultivars. Clearly, in the opposite of what is observed in other countries (with likely the exception of India where hybrid cultivars are disseminated too), the GMC characteristic is not responsible for the high increase of the seed cost in China. The diffusion of hybrid cultivars is. The approach of diffusing hybrid cultivars is leading Chinese cotton growers of Jiangsu Province to pay GMC seeds at a level close to what is encountered in other countries, notably the developed ones. This convergence was not observed in Hebei Province a couple of years ago when mainly open-pollinated cultivars were disseminated (Fok, Liang, et al., 2005). According to discussions with a few seed distributing companies, the seed cost tends to be around US$ 120/ha now.

The large adoption of hybrid cultivars looks amazing owing to their high seed cost, it can be understood by the generalization of the cotton transplanting technique in the surveyed villages where all farmers acknowledged the advantage of using hybrid cultivars to decrease the plant density, hence the labour requirement at the transplanting stage.

3.2. Intensive cropping and chemical pest control under evolution

Chemical products commonly involved in cotton production in China are growth regulators, mineral fertilizers and pesticides. The use of growth regulator is somehow systematic. In Jiangsu Province, our survey found that farmers apply in general growth regulator three times for a total cost of about US$ 8/ha, with products manufactured locally at price far much lower than products commonly used in developed countries.

In terms of fertilizing, farmers combine diversely nine types de fertilizers, several of them are of low nutrient concentration. Consequently, the total amount of commercial products is high, about 1250 kg/ha. Our survey does not reveal difference in fertilizing in relation with the type of varieties farmers used.

Farmers mainly use insecticides to control cotton pests. In our survey, farmers demonstrate a quite good knowledge of the cotton pests and beneficials. Farmers mention seven pests that must be controlled to prevent economic damages. As indicated in Table 6, farmers report evolutions of the pressures for various pests. These evolutions can be related to about ten years of Bt-cotton use. Pest pressures for bollworms have decreased, but they have clearly increased for red spider and lygus. The farmers' observation confirmed the increasing threat of Spodoptera litura, a caterpillar known commonly as a leaf eater and which is also damaging various fruiting organs. The reduction of bollworm pressure was expected from the use of Bt-cotton and was confirmed by the first impact assessments of this use. The increasing threat of pests formerly considered as secondary ones was somehow overlooked.

Farmers mainly rely upon using insecticides to control cotton pests, although some of them can mention non-chemical control method such as the use of trap plants and hand destruction, as well as the use of Bt-insecticide.

Our survey tried to capture the number of chemical controls farmers applied for each pest for which they used distinct active ingredient. On average, for those farmers who answered, farmers implemented in total 14.4 controls in 2005, which must correspond to a smaller number of sprays as several controls can be combined into the same spray. Not all farmers applied insecticides against all cotton pests. In fact, if all farmers fight against the most common pests like bollworms, aphids and red spiders, this is not the case for pests like Spodoptera litura or lygus. The sum of the average control numbers for each individual pest consequently is different of the total number of controls implemented. These average numbers nevertheless remain interesting. They indicate that H. armigera and pink bollworm still need respectively about four and three chemical controls. It comes out that Spodoptera litura, a Lepidoptera generally overlooked, at least need one control. Non-lepidoptera pests, like sucking pests, are requiring as many chemical control as Lepidoptera ones, if not more. There seems to be a more relative importance of non-lepidoptera pests to be controlled and which go beyond the power of Bt-cotton varieties.

In terms of costs, the chemical control is representing around US$ 100/ha with some variation according to the types of varieties farmers used (Table 7). The few farmers who did not grow Bt-cotton tend to implement 2-3 controls more, and which are targeted at H. armigera. Because the number of these farmers was too small, the differentials in the insecticide cost we observed are only indicative. Users of Bt-cotton spent US$ 92/ha, while users of non Bt-cotton spent US$ 142/ha, or US$ 50 more. In this total cost, the control of Lepidoptera pest accounts for slightly less than half.

3.3. GMC adoption with limited yield and profitability gain

There is not yet systematic use of hybrid cultivars or Bt-cotton cultivars. Our survey confirm that farmers are still using the four possible types of cultivars (Hybrid and Bt-cotton, Hybrid and non-Bt-cotton, Non-hybrid and Bt-cotton, Non-Hybrid and non-Bt-cotton) but their distribution is very unbalanced with predominance of hybrid and Bt-cotton users. As not all farmers responded to the questions related to their production costs, we miss information on farmers who use hybrid but non-Bt-cotton cultivars. Besides, the number of farmers who use cultivars which are not hybrid or GMC cultivars was very small. The figures of the Table 7 have only indicative value and must be confirmed by further research work.

Under the reservation above mentioned, it seems that there is no productivity and profitability advantage from Bt-cotton when non-hybrid cultivars are considered. This observation is consistent with some previous research works (Xu, You, et al., 2004). The partial results we obtained from our survey do not enable us to pronounce in the case of hybrid cultivars and which were not specifically considered in previous research works.

Nevertheless, the advantage derived from hybrid cultivars appears to be very substantial in spite of the high seed cost which is largely compensated by far higher yield. This observation confirms the rationale of the farmers' adoption of hybrid cultivars, at least in Jiangsu Province where transplanting is implemented.

We tried to complement our findings through the exploitation of available data. For more than fifty years, varietal experiments are implemented before the varieties are authorized for commercial release. These experiments are coordinated within regionalized networks in China. Jiangsu Province is integrated into the network of the Yangtze River Valley which encompassed 23 sites scattered in eight provinces. The results of the last five years (from 2001 to 2005) have been computerized and can be processed to assess the impacts of GMC or hybrid cultivars. These results pertain to 1379 seedcotton yields of various sets of varieties being compared. The varieties can be categorized for their GM feature and hybrid nature. Among the whole set of results, 1099 correspond to hybrid varieties (average yield of 3360 kg/ha, std error of 705 kg/ha), and 280 correspond to non-hybrid varieties (average yield of 3225 kg/ha, std error of 675 kg/ha). With regard to the GM feature, 958 results came from GM varieties (average yield of 3330 kg/ha, std error of 690 kg/ha) versus 421 results for non-GM varieties (identical average of 3330 kg/ha, std error of 750 kg/ha). Fok and Xu (2007) give more elaborated presentation of these results.

It is clear that, at the level of multi-location experiment before the commercial release of varieties, hybrid and GM varieties far dominate. It is also clear that the GM feature brought no yield advantage, in the opposite of the hybrid feature whose positive effect on yield has to be tested.

Taking the seedcotton yield as a dependent variable, it can be assumed to be under the influence of various factors, notably the years, the provinces, the hybrid and the GM features of the varieties. The results of this model are shown in Table 8. Clearly, all the predicting factors we retain are significant except for the GM feature of the varieties. This outcome confirms that, at least along the Yangtze River Valley, there was no yield advantage resulting from the GM feature (in fact the Bt feature) of the varieties but the positive effect of the hybrid feature is significant. In other words, it seems hard to dissociate the diffusion of GM varieties from the adoption of hybrid varieties.

4. Factors of the GMC future

The adoption of GMC in Jiangsu Province is not only influenced by the specific efficiency of GMC cultivars as it is implicitly considered in most assessment studies of GMC use. Along the Yangtze River Valley, and notably in Jiangsu Province, this specific efficiency is of limited extent and furthermore seems to be on reduction. Other factors have contributed to the GMC adoption and will influence the future of this adoption, namely the relatively low specific cost of GMC seeds, the marketing strategy of cotton planting seeds and the evolution of the

Chinese farming.

4.1. Limited influence of the specific efficiency of GMC cultivars

In opposite to what is observed in many countries, the use of GMC cultivars does not lead to significant increase in yield in China. Where this has been reported, like in provinces along the Yellow River Valley, the increase was slight while such increase was seldom confirmed in provinces along the Yangtze River Valley. The absence of yield effect in this Valley is confirmed by the provisional results of our survey and by the exploitation of the results from the network of multi-location varietal experiments.

The use of Bt-cotton actually induces a reduction of 2-3 in the number of chemical control against bollworms, far less than what has been reported in provinces along the Yellow River Valley. This reduction implies some saving in insecticide use which is not translated into a better net income. This is partly due to the increase of seed cost and to the higher cost in controlling the pests against which Bt-cotton is not effective. This observation is consistent to what is now acknowledged in China. For all that, the use of GMC is not generating income loss, or not yet. It is normal that farmers keep on using GMC in Jiangsu Province in spite of the limited efficiency it specifically brings. This is opposite to what was encountered in some states in India where yield losses were attributed to GMC seeds (Anonymous, 2006; Qayum and Sakkhari, 2005).

4.2. Seed cost and marketing

Farmers in China have less reason to turn their back to GMC seeds because the specific cost of the GMC trait is low. In our survey, we observed that this trait generates only an additional cost of US$ 5-7/ha although farmers renew yearly their seeds. An even lower cost was found on average in Hebei Province in 2002 and 2003 where farmers held back seeds from one season to another (Fok, Liang, et al., 2005). This range of additional cost in using GMC, in absolute terms, is very low, at least ten times less than in other countries. In relative terms, the additional cost comes out to be furthermore small. Cotton cropping is very intensive in China and requires cash expenses for chemical use around US$ 350/ha against which the additional cost of the GMC trait represent less than 2%.

This additional cost of the GMC trait may not even been perceived by farmers because it is confused with the hybrid trait. Farmers favour using hybrid cultivars in Jiangsu Province because they are adapted to the transplanting technique which ensures high yield level. Farmers were using hybrid cultivars even before the advent of GMC and hence were accustomed to relatively high seed price. The injection of the GMC trait into hybrid cultivars provokes only a marginal increase in the planting seed price which may not properly be perceived.

The combination of the hybrid and GMC traits is becoming the general marketing strategy of seed distributors. The marketing approach of hybrid-GMC cultivars creates economic rents which can lead to excessive seed price. High pricing also results from the functioning of un-regulated seed market.

There has been a very dynamic release of new varieties resulting from the acknowledgement of breeders' right (Yang, 2005). The implication is the reduction of the lifespan of the proposed varieties as it is mentioned earlier. Every seed distributing company is expecting to provide one of the happy few cultivars having the farmers' favour. Marketing hence is critical through various means (notably TV ads), implying additional costs. The investment in carrying out and in promoting a new variety has to be paid back in a shorter and shorter period, implying automatically high seed pricing.

Yet, for Chinese cotton growers, the cost expense of seeds is quite similar to the one encountered in developed countries (USA, Australia) and it seems that it keeps on increasing at the expense of farmers' income.

The current situation of harsh competition is neither ensuring quality seeds to farmers. There is numerous seed production and distribution companies, but only the few large ones have the needed means to control that the seed producing farmers they contract are doing properly.

However the control and regulation system has not been updated to prevent some companies from competing through the release of fake hybrid seeds (Li and Liu, 2005). It is still common to encounter in the same village farmers producing seeds on behalf of distinct seed companies, of varieties which might be hybrids or not, Hybrid F1 or not (Li, Zhao, et al., 2005). The threat on seed quality is clear. At the level of cotton growers, the diversity of the varieties they used at the same location, with seeds whose purity is not guaranteed, is inducing the undesired effect of quality heterogeneity underlined by several recent studies (Lu, Tian, et al., 2006; Man, Xu, et al., 2006; Zhao, Wang, et al., 2005). The high level of technology characteristics embedded in newly bred varieties is not achieved at field level. These phenomena are detrimental to farmers (notably through yield loss) and to spinners (Man, Xu, et al., 2006).

The Chinese case illustrates the relevance of some regulation of the cotton seed market that the introduction of GMC has contributed to vitalize. A few cotton experts in China are asking for such a regulation (Liu, 2006). The absence of actions to correct the current trend of increasing seed price in one hand, and in the other hand to ensure seed quality could modify the adoption rate of GMC.

We actually have heard farmers complaining about the high price they pay for seeds and regretting the variety mixture phenomenon. This nevertheless might remain passive complain owing to the evolution of the farming in Jiangsu Province, like in many other provinces in China.

4.3. Farming and rural changes: factors of passivity?

The global income of farming families is increasing although its gap with urban families is increasing too (Figure 1). This is due to their involvement in off-farm activities which bring back regular wage income whose share is steadily increasing in contrary to the income resulting from cropping (Figure 2). The involvement in off-farm activities provides cash to afford rather high price seeds but it also tends to transform agriculture into a secondary activity for which the optimization target cannot be considered only through the mere reduction of production cost. The survey we conducted provides some evidence to this phenomenon.

In Jiangsu Province, according to our survey, farms are managed by people born after the establishment of New China, with an average age of 48, and having children who are around 30 year old. They cultivated on small farms of 6.4 mu (0.42 ha) with little prospect to increase their farm size. Cotton area was 3.6 mu (0.24 ha) on average in 2005, more than half of the available land. Farmers seldom have machineries for their agricultural production, our survey only recorded that all farmers had knapsack sprayers; some of them are equipped with a motor.

On average, there are three people per farming family of which 1.6 people are engaged permanently in field works. This is an indication of an important involvement in off-farm activities. About two third of the farms we interviewed had members engaged in off-farm activities, either permanently or occasionally.

The extent of the engagement in off-farm activities explain why the farmers of our survey responded that agriculture (cropping, husbandry…) is on average representing 52% of their total income. This is an indication of the secondary feature of agricultural activities in terms of income generation. This feature is reinforced by the instability of the agricultural income as a result of product price fluctuations that farming families cannot control.

The engagement in off-farm activities varies between generations and gender (Table 9). For the generation of the farm heads, the involvement in off-farm activities is important but not systematic and males are mainly concerned. For the generation of their children, this involvement can be regarded as systematic (when deduction is made of the children still going to school or university) and there is no difference between males and females. Clearly, farming in Jiangsu Province is becoming a part-time one and mainly led by ladies and old people as it was also observed in other provinces (Liang, Fok, et al., 2004).

This involvement in off-farm activities can lead the concerned people to migrate to locations far from their homes. This is not so much systematic. The migration out of their province of origin concerns only 20% of the people involved in off-farm activities, this phenomenon is generation and gender influenced. Young people and males tend to more migrate out of their province of origin. The wives of the farm heads seldom migrate out. This phenomenon of migration means that the concerned people have to leave their own children at home under the care of their parents, a task which adds to the agricultural activities.

All the same, farming families are showing some material welfare status. Our survey shows that they nearly all have durable consumer goods of modern life to save time, to alleviate hardness, to communicate or for leisure (Table 10). This is clearly a consequence of the income generated by off-farm activities.

The people who remain most involved in farming are now shared between more opportunities to have leisure time and more responsibility in taking care of their grand-children, the optimisation of some production costs does not seem to remain the unique target. This optimisation could even be questioned from the economic viewpoint. Efforts of optimisation can be nullified by unfavourable price fluctuations that farmers have been experiencing since the liberalisation of the agricultural economy and which severely hurt cotton production these recent years.

This phenomenon hence could discourage people from making the needed efforts. This seems to be the case. Through our interaction with farmers, we realized that they complain about high prices of production inputs, in particular seeds, as well as about low purchasing price of the seedcotton they produce, but we felt no real intention of individual or collective moves to reverse these trends. Kind of vicious circle seems to be taking place. Farming is becoming secondary activity. This is leading to reduce efforts to optimize production costs, inducing lower and more unstable agricultural income which makes agriculture appear furthermore secondary in generating income.

5. Conclusion

There is a general tendency to appraise the adoption of GMC through the specific advantages it might bring. This approach is debatable as it is disconnecting this technology to existing technologies which may make GMC more or less attractive. China is providing an example to sustain the relevance of more comprehensively looking at the various factors which influence the GMC diffusion. Cotton growing in China has benefited from a series of remarkable and adapted technology achievements carried out well before the GMC introduction, namely transplanting and hybrid breeding. In Jiangsu Province, the specific yield advantage of GMC cultivars is of limited extent. In this province, the diffusion of GMC and its continuation hence are not due only to the GMC specific advantage but rather to its integration into hybrid cultivars which are perfectly adapted and profitable to the transplanting technique. This experience in Jiangsu Province indicates that the prospective appraisal of GMC use in other countries will gain from an assessment of how much GMC would be compatible to existing production technologies in these countries.

This more comprehensive approach also enables to predict that a reduction in effectiveness will not necessarily lead farmers to abandon GMC use. Nevertheless, the functioning of the cotton seed market leads to high pricing. If seed price keeps on rising as it is now observed and if seed quality is not ensured by lack of control and certification, or in other words if no regulation is implemented in the seed sector, farmers could modify their behaviours in buying seeds. Of course, the secondary characteristic of agriculture in farming families is corresponding to some level of inertia against this behaviour change, but the seed price has increased so much these recent years that the acceptable price level might have been approached yet. The Chinese experience points out that the regulation of the seed sector to accompany a smooth and profitable use of GMC is an issue which must be better considered.

Table 1. Evolution of cotton production in Jiangsu Province, China

	1981-85	1986-90	1991-95	1996-00	2001-05	Average
Area, 1000 ha	660	430	560	370	350	491
Area, %	11.4	11.0	9.7	8.9	7.7	10.1
Lint Yield, kg/ha	884	692	894	1075	1183	868
Lint production, t	589	378	506	413	411	466
Production, %	13.7	12.0	11.0	9.6	8.0	11.1

Source: Xu, LiHua & Ji, CunMei, 2005

Table 2. Evolution of the area of transplanted cotton in Jiangsu Province

	Total cotton area	Cotton area by transplanting	
	1000 ha	1000 ha	%
1977	583	73	12.4
1978	585	80	13.6
1979	589	137	23.2
1980	587	250	42.6
1981	659	339	51.4
1982	703	409	58.2
1983	677	496	73.3
1984	725	563	77.7
1985	592	505	85.3
1986	497	392	78.9
1987	500	434	86.8
1988	587	507	86.4
1989	536	475	88.6
1990	553	480	86.8

Source: Zhu et al. 1991

Table 3. Comparative advantages of transplanted cotton (results of early 1980s)

	Plant height cm	Fruit branch No./plant	Fruit position No./plant	Boll No./plant	Boll set %	Boll weight g	Seedcotton yield Kg/ha
Transplanting	103.4	17.1	52.2	15.7	30.2	3.59	2726
Direct sowing	93.2	13.5	43.8	11.8	26.9	2.95	2025

Table 4. Diversity and concentration of the cotton varieties being used

	2004	2005
Total number of varieties encoutered of which	21	26
GM & hybrid varieties	9	17
GM & non-hybrid	8	5
Non-GM & hybrid	0	1
Non-GM & non-hybrid	4	3
% of farmers using		
TOP 1 variety	36.9%	24.6%
TOP 3 varieties	62.5%	57.9%
TOP 5 varieties	77.8%	73.8%

Source: our survey

Table 5. Distribution of the farmers according to the cultivar types

	Hybrid varieties		GM varieties	
	Yes	No	Yes	No
Farmers using, %	79.0%	21.0%	91.4%	8.6%
Planting seed price, US$/ha				
Mean value	92.1	12.4	79.4	32.8
Standard deviation	25.3	9.5	37.1	37.7

Source: our survey

Table 6. Farmers' practices and feeling about pest control

	Average number of chemical control	% farmers feeling that the pest pressure is			
		stable	decreasing	increasing	fluctuating
Helicoverpa armigera	4.1	4%	69%	9%	17%
Pink Bollworm	3.0	4%	53%	1%	15%
Spodoptera litura	1.5	3%	1%	57%	25%
Aphids	2.0	41%	7%	23%	22%
Lygus spp.	3.0	2%	2%	45%	40%
red spider	3.2	35%	2%	35%	24%
Yellow cutworm	1.0	21%	15%	3%	35%
Other	2.4	0%	0%	13%	0%

Source: our survey

Table 7. Cotton production cost and income according to the types of cultivars used

	Non-Hybrid varieties		Hybrid varieties
	GM	non-GM	GM
Planting seed cost, US$/ha	13.7	8.7	92
Growth regulater, US$/ha	7.1	7.1	7.1
Fertilizers Amount, kg/ha	1252	1252	1252
Fertilizers Cost, US$/ha	249.0	249.0	249.0
Number of pest controls	14.0	16.7	14.0
Cost of pest control, US$/ha	96.0	142.0	96.0
Seedcotton yield, kg/ha	3232	3457	4395
Gross income, US$/ha	1569.0	1678.0	2133.0
Income net of input expenses US$/ha	1203.2	1271.2	1688.9

Source: our survey

Table 8. Influencing factors of the seedcotton yields in multi-location varietal experiment

	Unstandardized coefficient		Stdzed coeff.	t	Sig. level
	B	Std error	Beta		
Constant	284.059	7.607		37.343	.000
GM factor	-4.601	2.941	-.045	-1.565	.118
Hybrid factor	-13.687	3.162	-.117	-4.329	.000
Province factor	-3.619	.651	-.146	-5.560	.000
Year factor	-6.714	.953	-.202	-7.044	.000

Source: Multi-location varietal experiment Network of Yangtze River Valley

Table 9. Great extent of engagement into off-farm activities

	Types of family members concerned			
	Generation of farms' heads		Children of farms' heads	
	Male	Female	Male	Female
% farms with engagement in off-farm activities	55%	24%	80%	86%
of which permanently	24%	2%	58%	54%
occasionally	30%	22%	22%	32%
Distribution of the farms involved in off-farm activities according to the locations of these activities				
within the district of the farms concerned	71%	95%	40%	53%
Out of the district of the farms concerned				
of which, within the same province	14%	5%	31%	28%
out of the Province	15%	0%	29%	19%

Source: our survey

Table 10. Material welfare in farming families

	% of farmers having	having one	having more than one
Bicycle	95%	44%	51%
motobike	48%	43%	5%
Fixed phone	80%	78%	2%
Mobile phone	53%	39%	14%
TV set	95%	75%	20%
Rice cooker	77%	73%	3%
Microwave_oven	14%	14%	0%
Electric fan	96%	23%	73%
Washing Machine	59%	57%	1%

Source: our survey

Figure 1. Increasing income gap between rural and urban families

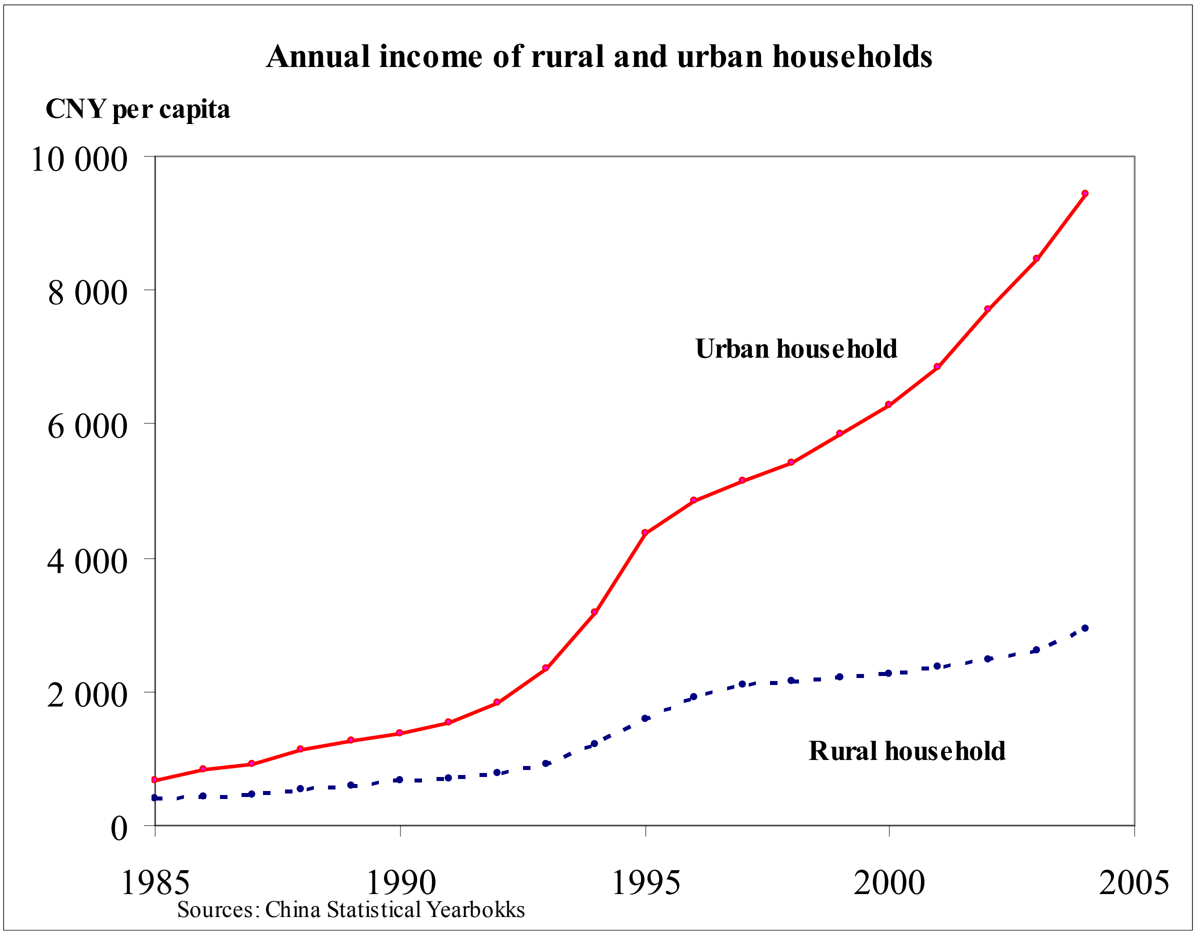
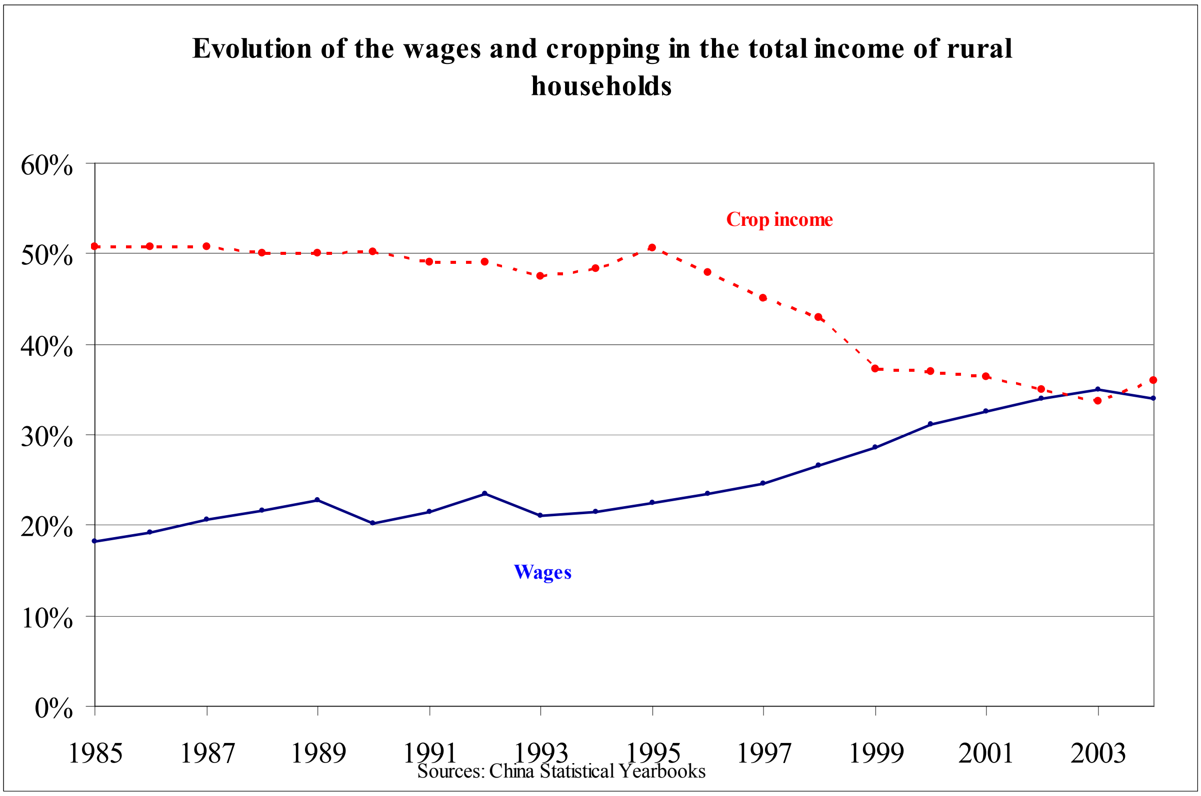


Figure 2. Decreasing contribution of cropping to rural households' income



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